


Fusion Product Deposition and Energy Balance

W. C. Condit
Lawrence Livermore Laboratory

D. E. Driemeyer
University of Illinois

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Lawrence
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Fusion Product Deposition and Energy Balance

W. C. Condit and D. E. Driemeyer

We have performed extensive Monte-Carlo calculations of alpha-particle deposition in the Hill's Vortex configuration, as reported in D.E.Driemeyer's Ph.D. Thesis (University of Illinois, 1980). This has generally been done including a cold plasma density, n_c , on the open field lines, with $n_c/T_c^{3/2} \cong n_H/T_H^{3/2}$ -- i.e. with the slowing down ratio τ_H/τ_c lying between .1 and 10. Since many of the alpha particles spend a significant amount of their time on the open field lines, values of τ_H/τ_c greater than unity lead to significant removal of alpha-particle "ash" from the closed-field region. Surprisingly, we are able to perform this ash removal and still retain enough energy to raise the reactor Q significantly (or even ignite it).

The fraction of alphas confined completely within the closed-field region, f_{CF} , and the fraction, F_{AC} , confined absolutely (including some excursions onto open field lines), are shown in Fig. 1. It turns out that we can write excellent correlation formulae:

$$(1^a) \quad f_{RE} = f_{CF} + f_{MCE}(f_{AC} - f_{CF}) \text{ -- Retained Energy}$$

$$(1^b) \quad f_{RP} = f_{CF} + f_{MCP}(f_{AC} - f_{CF}) \text{ -- Retained Particles}$$

for the retained alpha energy and particle fractions. We find

$$(2)^a \quad f_{MCE} = -.4288 \log \frac{\tau_H E_D}{\tau_c \log(E_0/T_i)} + .2504$$

$$f_{MCP} = -.3501 \log \frac{\tau_H E_D}{\tau_c \log(E_0/T_i)} + .3450$$

These formulae correlate a large number of Monte Carlo results for both alpha particles and 14 MeV proton deposition in advanced-fuel reactors.

Figure 2 shows details of the correlation, and Figs. 3-5 show the reactor energy-gain values computed by incorporating $(1)^a - (1)^b$ into an energy balance code which includes neutral-beam and auxiliary heating, classical or enhanced particle losses (at the user's option -- cf Fig. 3 vs Fig. 4), bremsstrahlung losses, and beta-corrected synchrotron radiation losses. Even for advanced fuels, the results are encouraging.

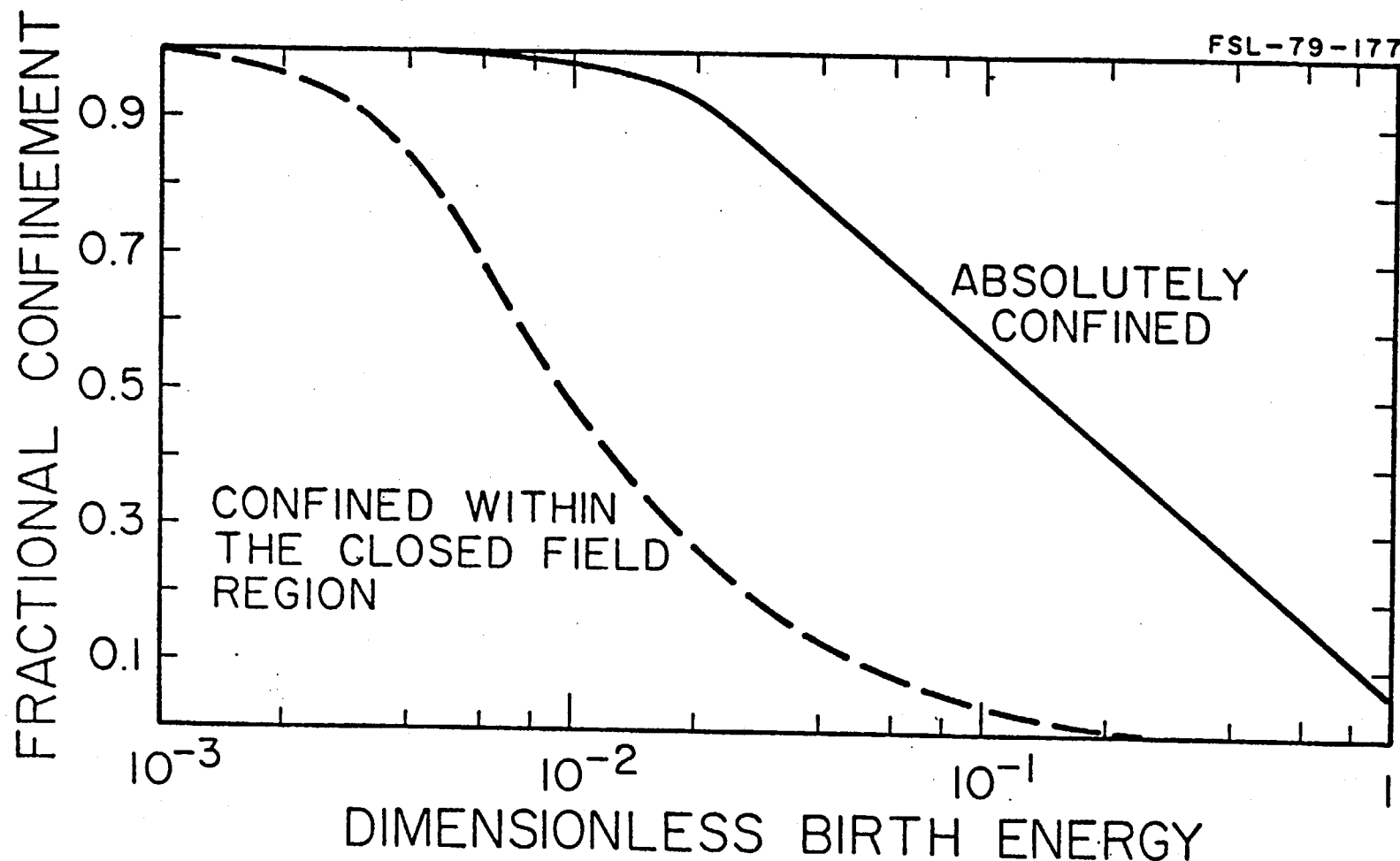


Figure 1 Confinement limits for fps in the FRM as a function of their dimensionless birth energy $mc^2 E_0 / (qB_0 R_{HV})^2$. The upper "absolutely confined" curve corresponds to the fraction of fps that have $E < -P_\theta$, while the lower curve corresponds to those that, furthermore, have $\sqrt{2E} < -P_\theta$.

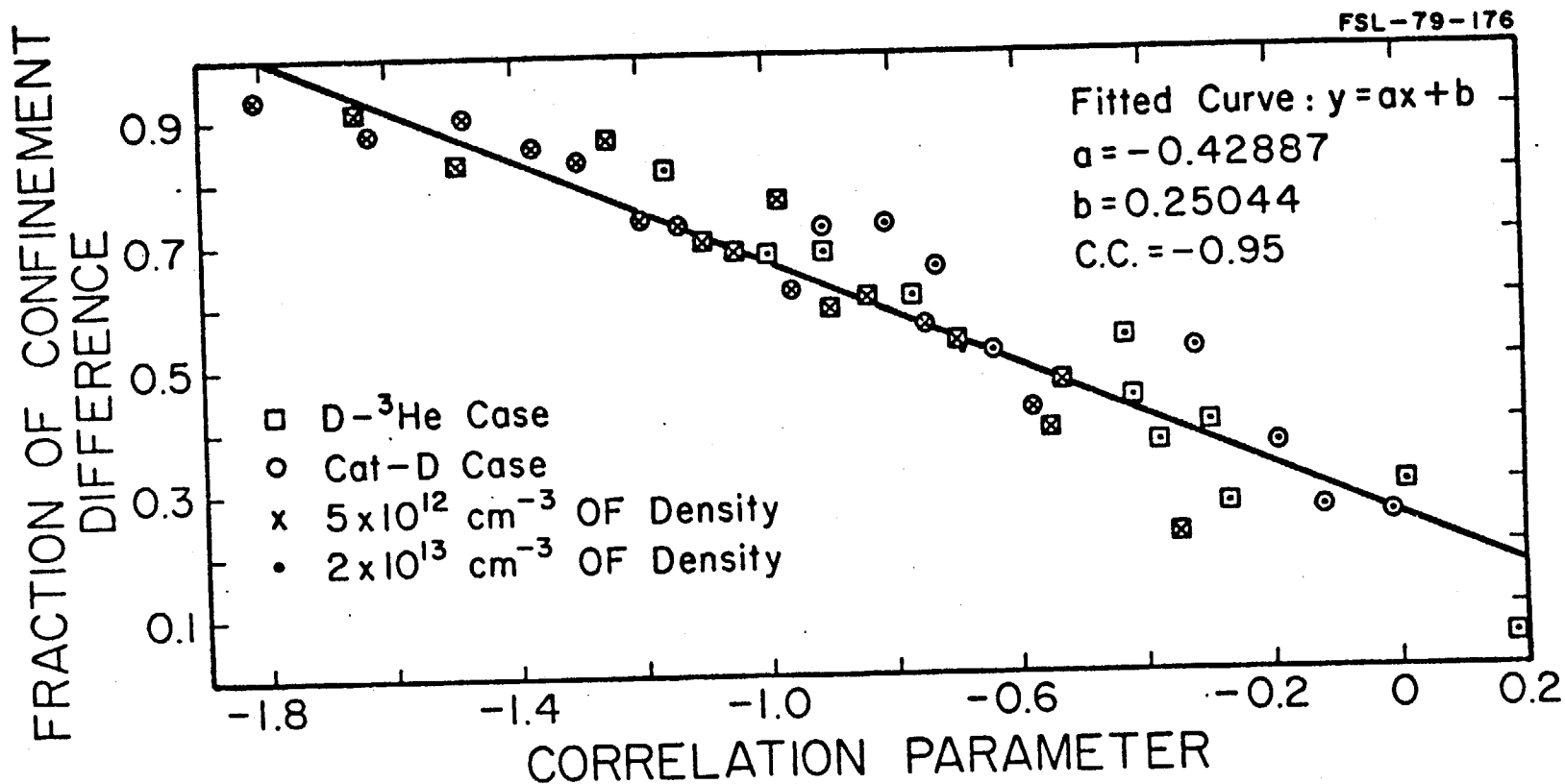


Figure 2 Correlation of the MCFRM results for the fracture of the marginally confined fp energy that is deposited in the closed field region for typical FRM plasmas. The correlation parameter is $\log [(\tau_H/\tau_C)E_D/\log(E_0/T_i)]$ and the correlation coefficient is -0.95. The line is used to estimate fp energy deposition in the FRMOD code.

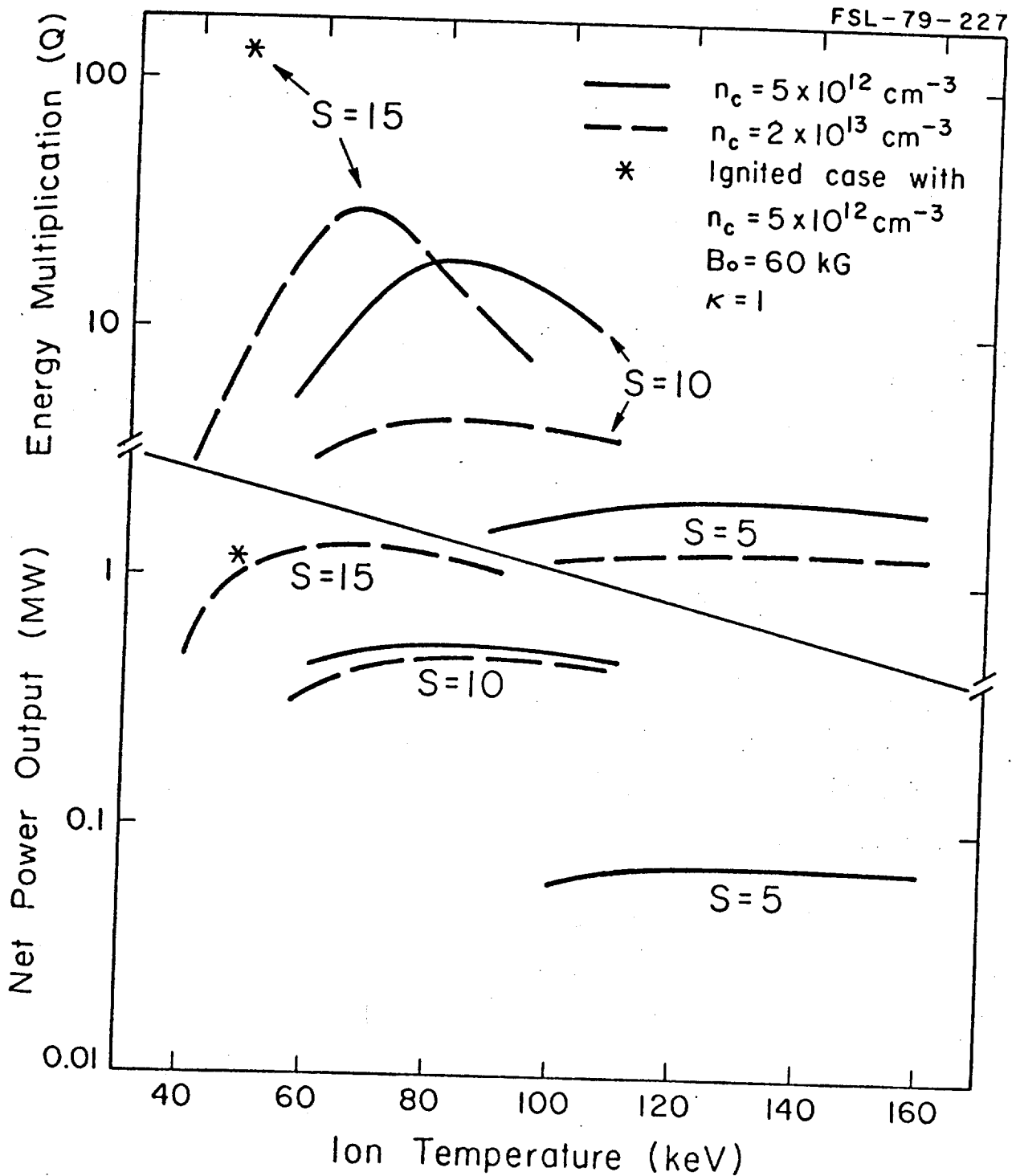


Figure 3 Energy multiplication factor and net power output vs the plasma ion temperature for D-³He systems with "near-classical loss rates ($\tau_{\text{particle}} = \tau_{\text{class}}/3$).

n_e = density of $s = a/\rho_i$ = ratio of density scale length to vacuum-field gyroradius at given ion temperature.

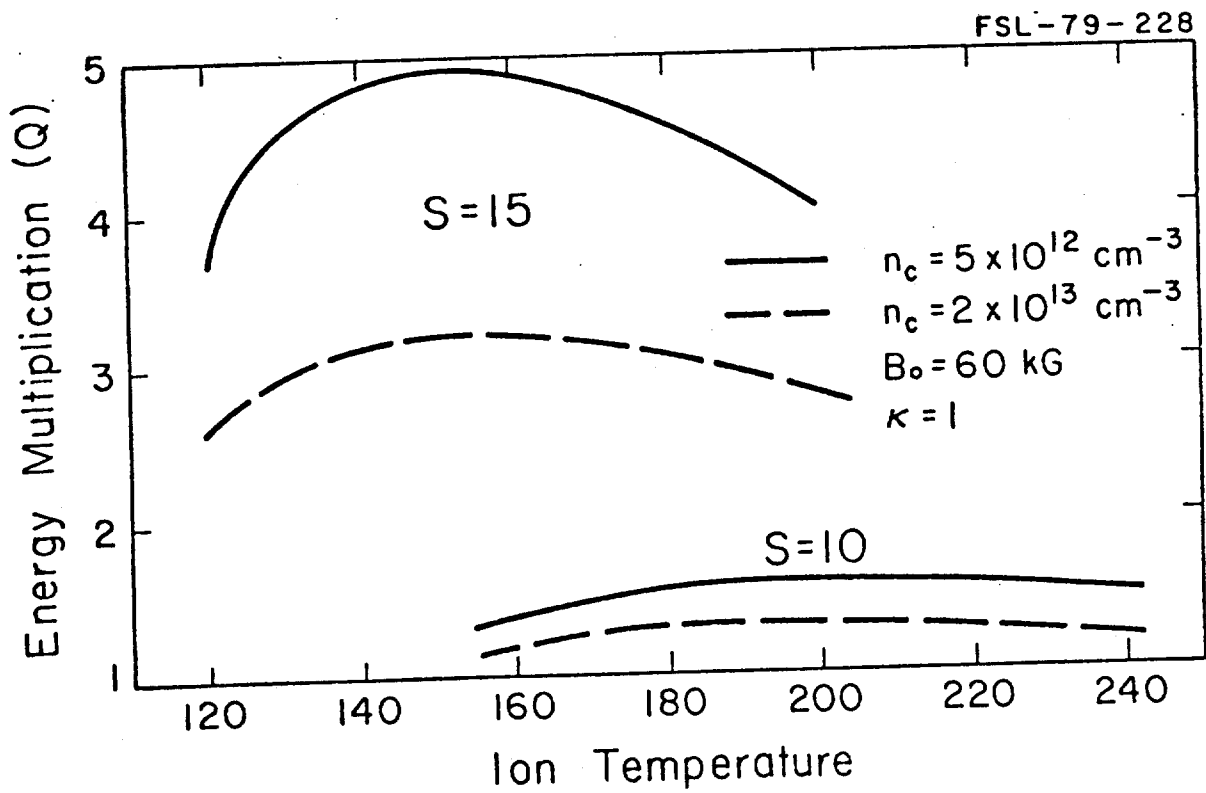


Figure 4 Energy multiplication factor vs the plasma ion temperature for D-³He systems with anomalous loss rates.

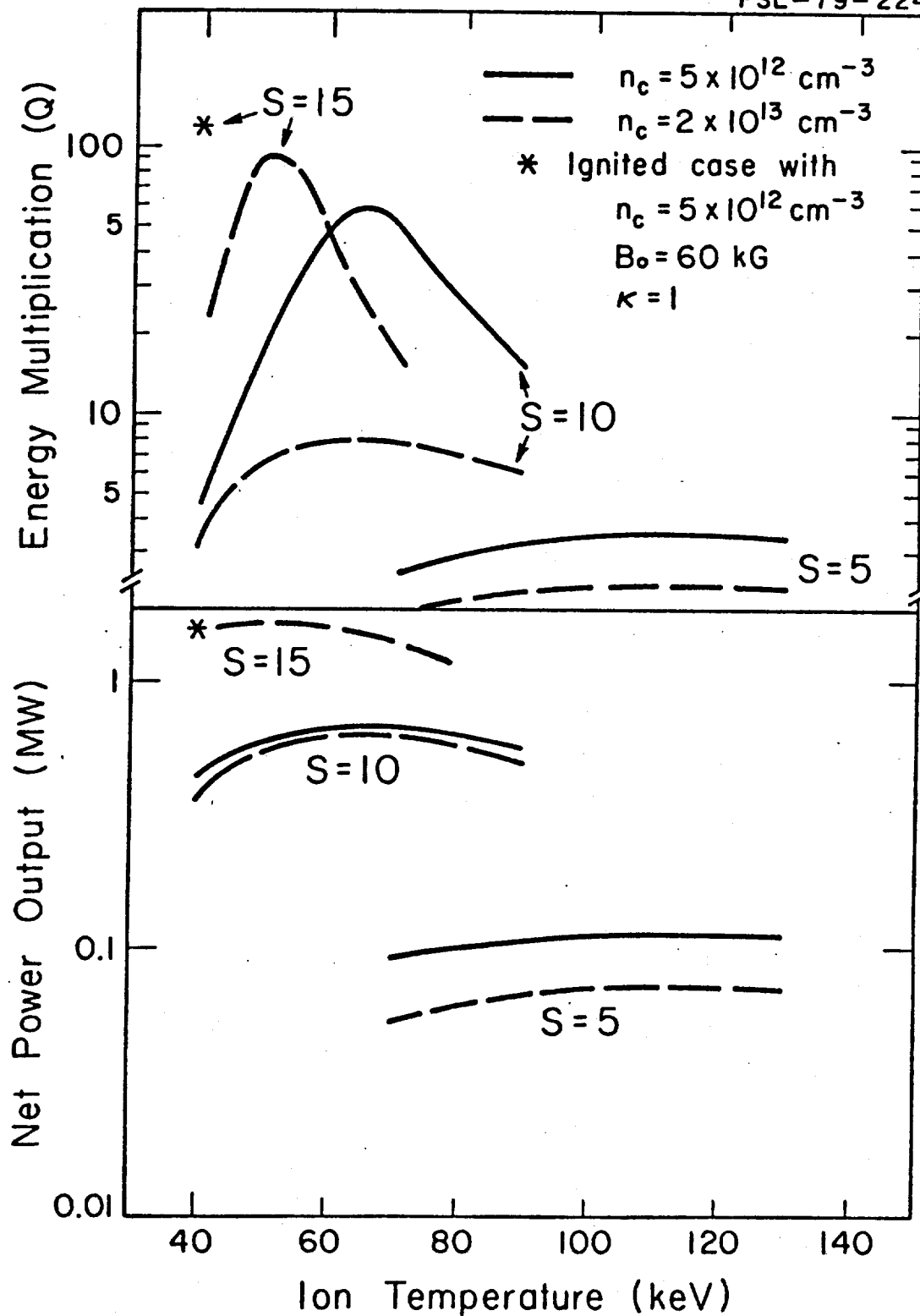


Figure 5 Energy multiplication factor and net power output vs the plasma ion temperature for Cat-D systems with "near-classical" loss rates. n_c = density of cold "scrape-off layer" outside separatrix.

